# Electrical Vehicles: A Blessing or Challenge for Smart Grid in Presence of Renewable Energy Resources

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# Electrical Vehicles: A Blessing or Challenge for Smart Grid in Presence of Renewable Energy Resources

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**Abstract.** Environment deterioration, energy shortage and ever rising fuel price makes green transportation a necessity. Being an alternative to fossil fuels vehicles, Electric Vehicles (EVs) exemplify the most popular approach of electrification to a substantial portion of the transportation sector. Recently, usage of renewable energy resources (RERs) is also increased because of its economic and environmental concerns over traditional resources in the new electric power systems. Variable reliability aspects of RERs increase the complexity of safe and stable operation of grid. Therefore, EV will further increase this uncertainty and variability when being connected randomly to the grid in large scale. This paper not only highlights the EV's related challenges/issues and presents a brief comprehensive review of recent researches. But, also demonstrates a simulation methodology for analyzing the impact of EVs under various charging scenarios on an independent distribution grid in presence of RERs. The results show the creation of new peak loads which in some cases may exceed the grid capacity and threaten the stability and reliability.

## Introduction

The target of decreasing fossil fuel consumption with improved efficiency as well as environmental protection has focused the world's attention towards the electrification of vehicles[1]. As a promising future of transportation sector, EVs are considered as a best alternative that not only decreases the dependency on fossil fuels with low cost but also increases the efficiency. EV's potential social, environmental, and economic impacts are being studied in vast amount throughout the world. But still few issues are left that deserves broad research attention and needed to be exploring more. For example, evaluating the impacts of the mass adoption of EV on the power grid when it is connected with intermittence energy resources, especially on the distribution level and proposing possible solutions to these challenges in concern of competitive electricity market. Until now very few researches have been done in this regards[2-4]. Several research studies had focused primarily on EV integration impacts on determining whether existing power system generation capacity is capable of fulfilling the new load demand of EVs. Possible impacts of EVs on demand increase , price , generation and Green House Gases emissions have been explored in [5-11]. It is very crucial and critical to understand the implications of EVs addition onto the grid at distribution level in presence of DG as there is very limited options are available for improvement and modification. In this article a comprehensive state of the art review is also presented for various types of EVs, their mode of operations, their effects on the power system. A model is developed to examine impacts of EVs charging in presence of renewable energy resources (RER) on an independent micro grid under different charging scenarios.

## Electrical Vehicles

According to the definition given by the IEEE "These are the vehicles having at least: (1) a battery storage system of 4 kWh or more, used to power the motion of the vehicle; (2) a means of recharging the battery system from an external source of electricity.

**Concepts of Operation.** EV's modes of operation can be defined into two concepts based on the direction of power flow, namely "charging mode or Grid-to-Vehicle (G2V)" and "generation mode or Vehicle-to-Grid (V2G)". These two operation modes of EVs have the different impact on the power grid and need to be analyzed separately due to mass deployment of EVs in the future.

**Vehicle-to-Grid Mode.** V2G is one of the important modes of operation that can be served as energy-storage devices. It allows new opportunities of supplying electric power to stressed grid by providing ancillary services.

**Existing Setups for V2G.** Three major setups for V2G operations are present that are:

1) Fuel cell vehicle: This type of vehicle generates power from its storable fuel (conventional fossil or hydrogen) by using generator and produces power for a utility at peak electricity usage times.

2) A battery-powered vehicle: Excess battery capacity is utilized to supply power to the utility grid at critical time.

3) A solar vehicle: Solar energy is used for charging battery and supply to the utility grid.

**V2G Related Opportunity and Challenges: A Review.** V2G technology enables bi-directional interaction among vehicles and grid that greatly affect the commercialization of restructured electrical market. It provides an innovative idea of supplying electric power to the utility grid in response to regulation requests, peak load demands or spinning reserve. Thus, V2G mode can provide ancillary service to the grid by increasing its reliability and stability; lower the costs of electric system with substantial financial return for the service. Intermittence and volatility of generated power from RERs made it impossible to connect them directly to the grid. However, V2G technology is greatly helpful that enables safe integration of such renewable energy resources with grid[8].

## Grid-to-Vehicle Mode

In charging mode, EVs are considered as a special type connected load to grid that has unique characteristic of controllable charging process for its batteries.

**Charging Mode.** Generally, four various type of charging mode are existing that are :

1) Uncontrolled charging: In this type of charging mode of EVs, charging take place in uncontrolled manner at home when connected.

2) Delayed charging: Although, all type of charging takes place at home. However, owner of EV seeks to better optimize the utilization of off-peak energy rate by delaying initiation of household charging until 10 p.m.

3) Continuous charging: In this mode of charging, EV is continuously charged whenever it is parked, using charging facilities available either at home or in charging stations.

**G2V Related Opportunity and Challenges: A Review.** Usage of EV is stochastic in nature. It brings significant uncertain load when connect randomly to the grid in large scale. If no measures are taken into account then uncontrolled charging behaviors may lead to negative effects on supply/ demand balance, power quality, voltage control etc. This may leads towards the cascading failures, rolling blackouts, and other large-scale problems to the grid. Therefore, there must be some precautionary measures to overcome these foreseeable problems to make future power grid more reliable, stable to provide dependable power and self-configurable[9].

**Proposed Remedies.** One of the remedy to mitigate these impacts of EV's charging is to optimize battery charging profile for minimizing the peak power demand. This can be achieved by coordinate charging of different type of EVs such that these are not connected to the grid simultaneously. There are many methods for the coordinate charging, few of them are presented here briefly.

1) Staggered Charging: In these methods, latest communication infrastructure of the Smart Grid is used to manage the charging/discharging of EVs in a residential neighborhood and batteries are

charged one-at-a-time during off-peak hours (i.e. overnight).Various scheduling methodologies and techniques could be incorporated to ensure the equality of all vehicles request.

2) Proportional Charging: In this method, an intelligent charging controller would communicate with other charging stations and distribution transformer to know about the local load demands and to ensure customers ' charging preferences could be satisfied while improving load profile experienced by the distribution transformer.

3) Fully controlled charging

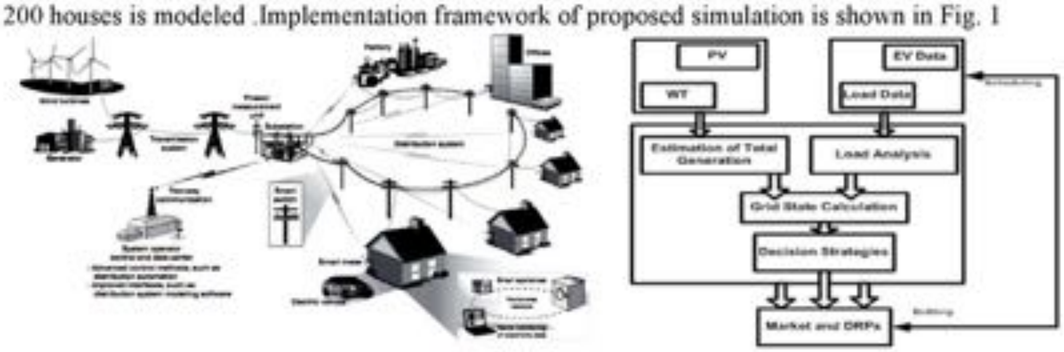
• Direct Method: One of the direct methods is to add an aggregator that have a control on charging and discharging of EV within a certain period of time and regulate the behavior of the customers based on the grid operating condition.

• Indirect Method: These methods include guiding or influencing the customer's behavior by using the price mechanism in the power market and offer various incentive policies.

4) Demand Side Management: Smart appliances such as EV will soon be able to "talk" to the grid and decide how best to operate and automatically schedule their activity at strategic times based on available generation.

## Simulation Description

For simulation purpose, an independent micro grid that is supplied by RERs and connected with 200 houses is modeled .Implementation framework of proposed simulation is shown in Fig. 1




(a) (b)

**Figure 1.** (a)Layout of future grid; (b) Implementation framework for proposed work

**Household Load Model.** For simulation, hourly residential load curves of an average household are modeled according to data available from the RELOAD database and [10].

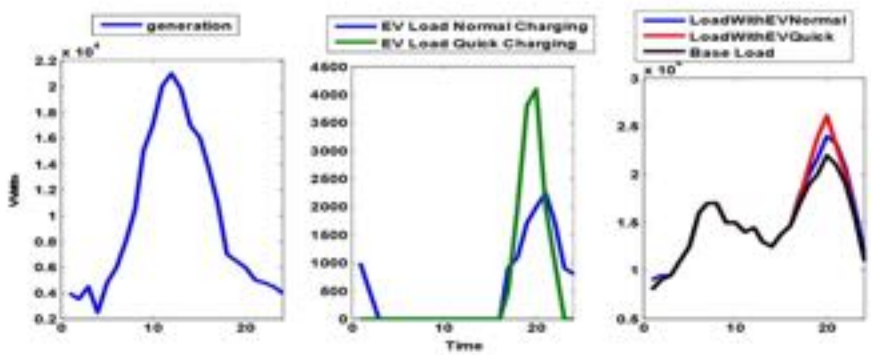
**EV Load Model.** It is found from researches that the plug-in time of EV is close to a normal distribution curve. Therefore, normal probability distribution function is used in simulation to describe that EVs come back home and plugged in at different time with the mean at 18:00 pm and the variance of 1 hour.

**Table 1**: EV specifications used in simulation

| Description | Values used in simulation |
|---|---|
| **Battery size** | 1k [Wh] |
| **Charging power required** | 3.3[kW] |
| **Available energy** | 8[kWh] |
| **Mileage** | 40 [mi] |
| **Normal Charging** | 110[V] /15[A] ; 6.5[Hrs] |
| **Quick Charging** | 240 [V] /30 [A]; 2.5 [Hrs] |

### Results and Discussion

Two types of EV charging strategies are considered for the proposed simulation: 1) normal and 2) quick charging. It is observed from peak load curve that it can be split into three different regions, called low load period (00:00 am–9:00 am), off-peak period (9:00 am– 5:00 pm) and peak period (5:00 pm–11:00 pm). As shown in Fig. 2(c), the peak of EV load with normal charging strategy is about 200kW and with quick charging strategy is about 500 kW. It is observed by the Fig. 2(b) that the peak demand load is increased with uncoordinated charging of EV, whereas the peak renewable generation is merely 21 kW. The reason for this is the highly volatile nature of renewable generations output that are based on the atmospheric conditions as well as their limited generation capacities in a remotely operated IMGN. Furthermore, the peaks of combined renewable generation and total demand load are not arising at the same time. This is because of the generation physics of renewable generation that a photovoltaic is more likely to produce peak power during the mid of day; while demand load is usually higher during nights. Thus causing seriously stability and reliability issues for the grid that is the main concern of this research. It is observed that reliability is reduced with the growth in peak load if the power generation are limited and become more pronounced when working in an independent mode as shown in Fig. 3.




a b c

**Figure 2**. (a) Load Curve without EV, (b) Generation-Load Curve, (c) EV Load Curve.

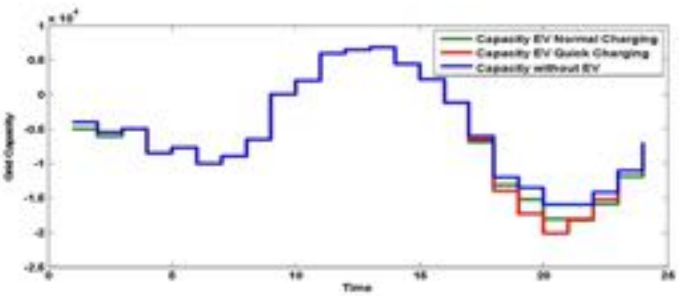



**Figure 3**. Grid Reserve Capacity Comparison under various charging scenarios

### Conclusion

It is concluded that it is still difficult to determine how much EVs technology will become lucrative and feasible in the future at this stage of time. It is expected that upcoming boom of EVs will increase day-by-day worldwide. However, it is sure that EVs have different impact to the security and economics of the existing power grids. Therefore we must prepare existing power grid and need to formulate reasonable scheduling plans to avoid the negative consequences and takes advantages of the positive ones. Finally, the joint scheduling of EV with other renewable energy is also important for integrating renewable energy with the grid. This should be manageable through advanced and smart techniques of future.

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